Faculty of Engineering
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3rd year Mechanical

Gear Cutting

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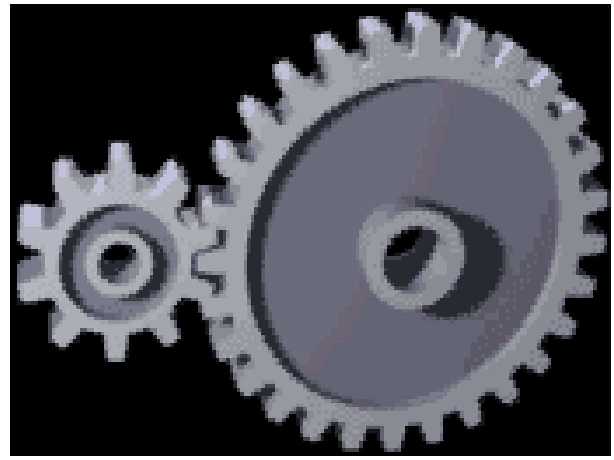
I- Introduction



Definition:

A gear or more correctly a "gear wheel" is a rotating part having cut teeth, which meshes with another toothed part in order to transmit torque with mechanical advantage.

Targets of gearing:

1- Enlarge torque.
2- Enlarge speed.
3- Change direction.
4- Transmit power from place to another far away with synchronization.

Advantages than other drives:

1- The definite velocity ratio:than belts due to slipping and wear especially in precision machines such as watches and other machines.
2- Positive drive: no slipping occurs; it depends on physical contact not friction.
3- Less power loss.

Disadvantages than other drives:

1- Difficult in manufacturing.
2- Expensive.
3- Need more parts for long center distance.
4- Need lubricating.
5- Difficult in installation.

II- Types of gears

1. *According to shafts relations and teeth directions:*

1.1- Parallel: Spur gears:

1.1.1. Straight.

1.1.2. Helical:

1.1.2.1. Line.

1.1.2.2. Curve (Spiral).

- Single.
- Double or herringbone.

1.2- Intersecting: Bevel gears:

1.2-1.1. Straight.

1.2-1.2. Helical.

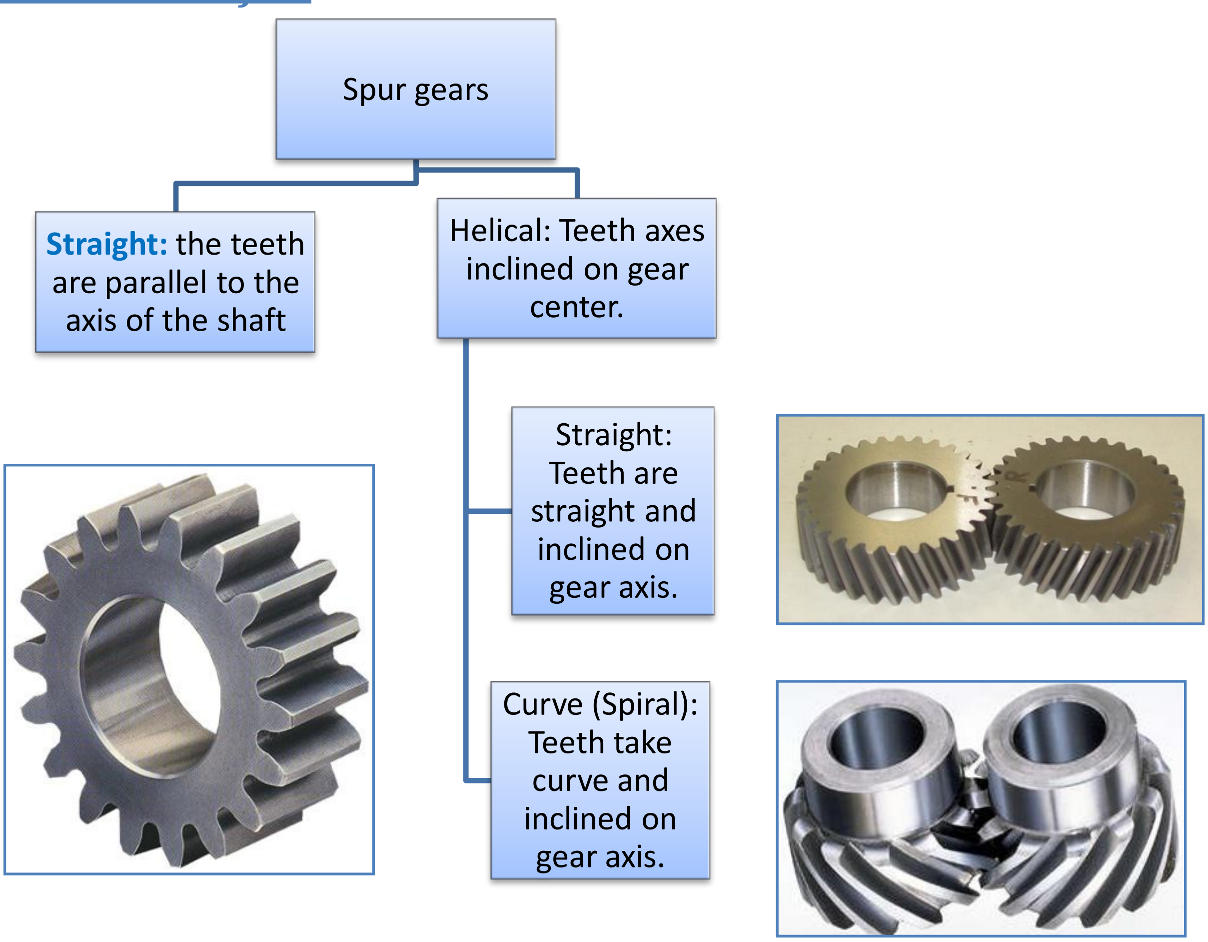
1.2-1.3. spiral

1.2-1.4. Hypoid.

1.3- Skew: Worm and worm gear.

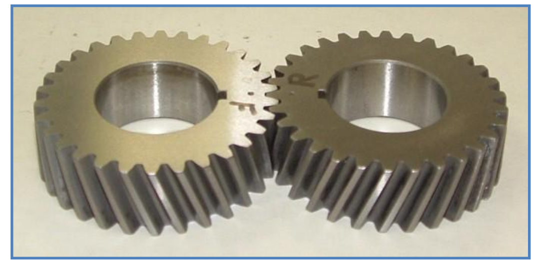
1.4- Rotational to linear and vice versa: Rack and pinion.

1.1. <u>Parallel Shafts:</u>



Helical gears

single gears



Herringbone gears: Herringbone gears resemble two helical gears that have been placed side by side. They are often referred to as "double helical”. One benefit of herringbone gears is that it helps to avoid issues related to side thrust created with the use of helical gears.

1.2. Intersecting shafts:

Bevel gears

Straight: the teeth are intersects the axis of the shaft

Helical: Teeth axes are skew with axis of shaft

spiral: Teeth take curve shape

Hypoid: cones aren't intersecting and contact between hypoid gear teeth may be even smoother and more gradual than with spiral bevel gear teeth.This style of gear is most commonly found driving mechanical differentials

1.3. <u>Worm and worm gear:</u>

Worm gears are used to transmit power between skew shafts and where high reductions arerequired but losses due to friction are high.

1.4. <u>Rack and pinion:</u>

A rack is basically a straight gear used to transmit power and motion in a linear movement and vice versa.

2. According to the type of gearing:

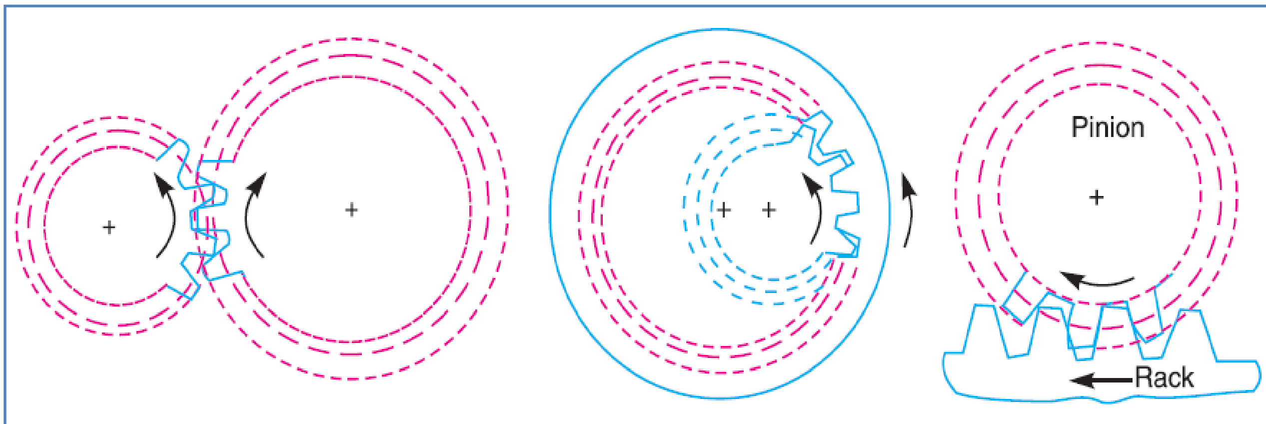
a. External gear *b. internal gear* *c. rack and pinion*

In external gearing two gears mesh externally. The directions of motions of two gears are*opposite.*

Easily manufactured/ not compact

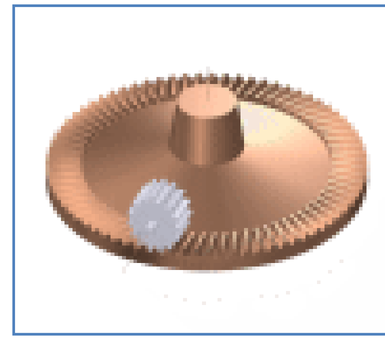
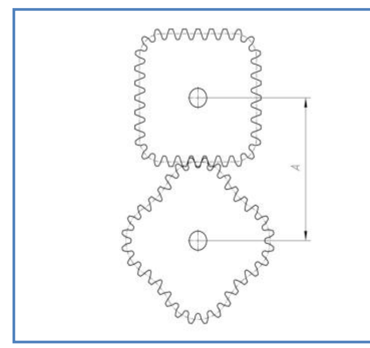
In internal gearing two gears mesh internally, the larger of these two gears is called *annular gear*; the motion of two gears is always *in same direction.*

Difficulty manufactured and installed/ compact



External gearing. Internal gearing. Rack and pinion.

Other types of gears

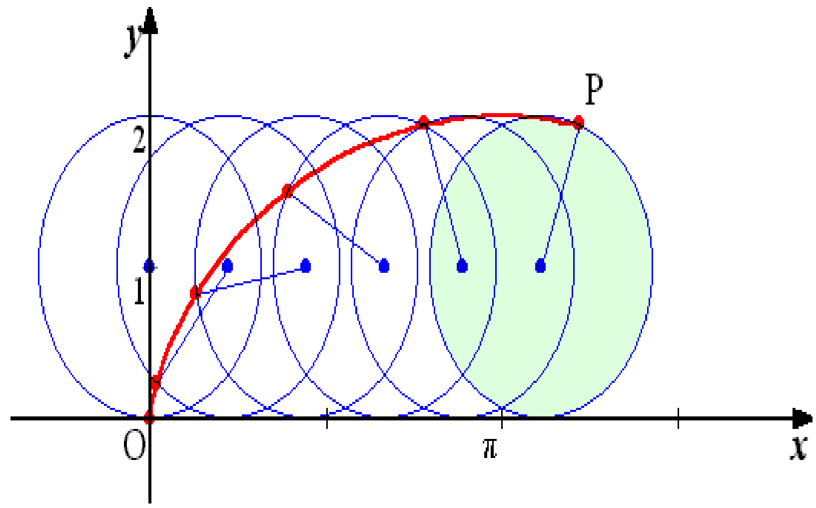
Gear	Properties	
Face/ crown Gears	Face gears transmit power at (usually) right angles in a circular motion. Face gears are not very common in industrial application.	
Non-circular gear	Non-circular gears are designed for special purposes. While a regular gear is optimized to transmit torque to another engaged member with minimum noise and wear and maximum efficiency, a non-circular gear's main objective might be ratio variations, axle displacement oscillations and more. Common applications include textile machines,	
Cage Gear	A *cage gear*, also called a *lantern gear* or *lantern pinion* has cylindrical rods for teeth, parallel to the axle andarranged in a circle around it, much as the bars on a round bird cage or lantern.	

III- Form of teeth

There are two types of teeth profiles commonly used,

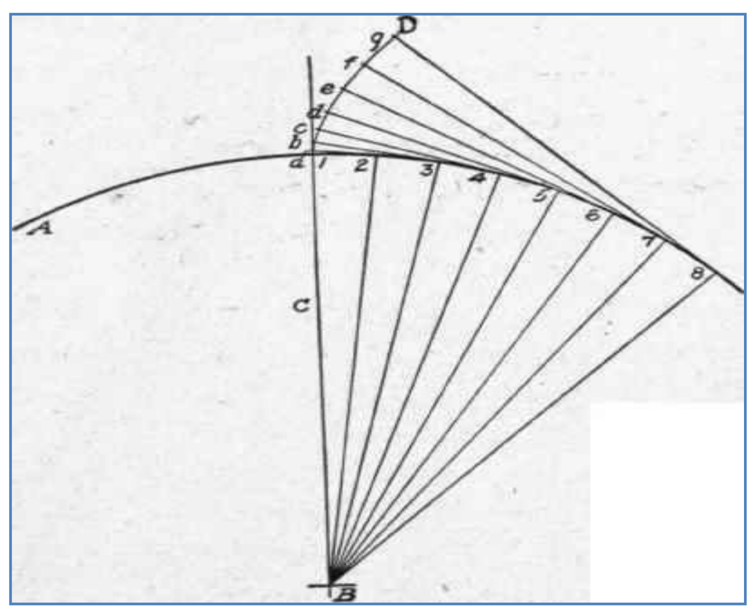
1. Cycloid teeth

Acycloid is the curve traced by a point on the circumference of a circle which rolls without slipping on affixed straight line. When circle roll without slipping on the outside of affixed circle, the curve traced by appoint on the circumference of a circle is known as epi- cycloid. On the other hand, If a circle rolls without slipping on the inside of affixed circle, then the curve traced by appoint on the circumference of a circle is called hypo-cycloid.



2. Involute teeth

The involute gear profile is the most commonly used system for gearing today. In involute gear design contact between a pair of gear teeth occurs at a single instantaneous point (see figure at right). Rotation of the gears causes the location of this contact point to move across the respective tooth surfaces. The path traced by this contact point is known as the Line of Action (also called Pressure Line or Line of Contact).

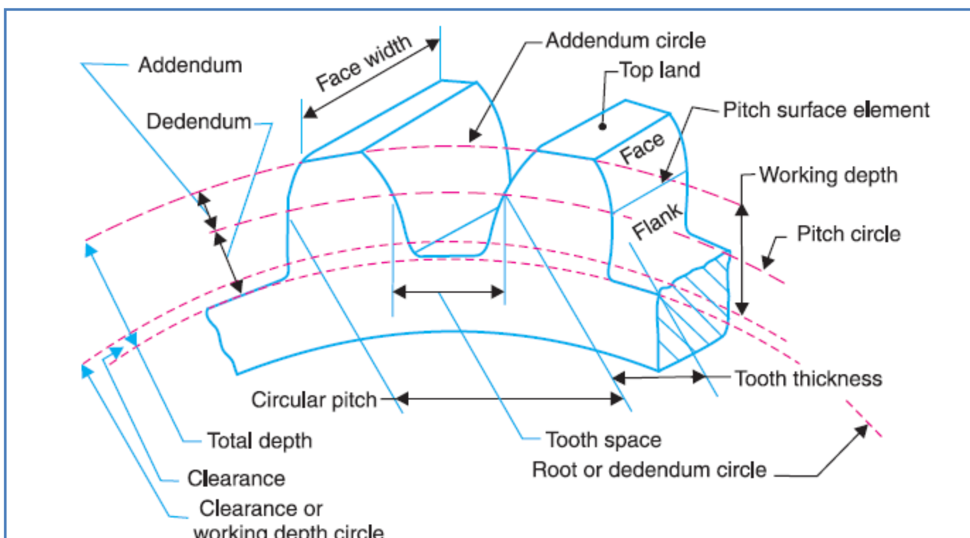


A property of the involute tooth form is that if the gears are meshed properly, the line of action is straight and passes through the Pitch Point of the gears.

Comparison between involute and cycloid profiles

	Involute	Cycloid
Advantages	- The center distance for pair of involute gears can be varied within limits without changing the velocity ratio this is not true for cycloid gears. - In involute gears, the pressure angle, from the start of the engagement of teeth to the end of the engagement, remains constant. -Easily manufactured (only one curve)	-Sincethe cycloid teeth have wider flanks, so the cycloid gears are stronger than the involute gears, for the same pitch .the cycloid teeth are preferred especially for *cast teeth* In cycloid gears, the contact takes place between a convex flank and concave surface but in involute gears, the convex surfaces are in contact that is **less wear** in cycloid gears.

IV- Tooth profile:



Terms used in gears.

Addendum (a): Radial distance from the pitch surface to the outer surface of the tooth.

a = m (std. gear)

Dedendum (b): Radial distance from the depth of the tooth through to the pitch surface.

Whole depth: The distance from the top of the tooth to the root; it is equal to addendum plus dedendum or to working depth plus clearance.

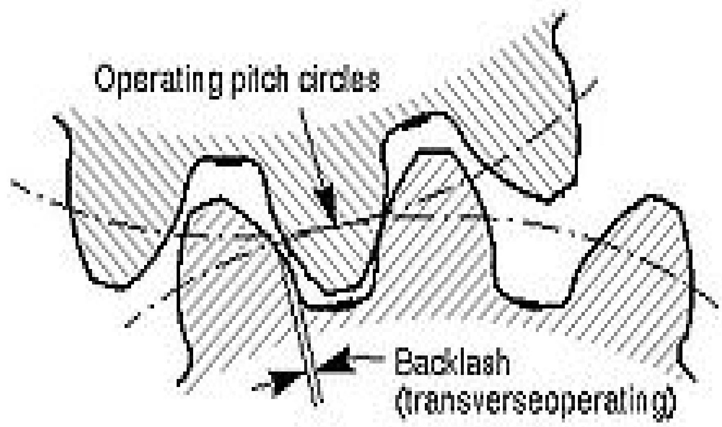
Clearance: Distance between the root circle of a gear and the addendum circle of its mate.

Working depth: Depth of engagement of two gears, that is, the sum of their operating addendums.

Circular pitch (p): Distance from one face of a tooth to the corresponding face of an adjacent tooth on the same gear, measured along the pitch circle.

Backlash:

In mechanical engineering, backlash, sometimes called *lash* or *play*, is clearance between mating components, sometimes described as the amount of lost motion due to clearance or slackness when movement is reversed and contact is re-established. For example, in a pair of gears, backlash is the amount of clearance between mated gear teeth.



Factors affecting the amount backlash required in a gear train include errors in profile, pitch, tooth thickness, helix angle and center distance, and run out. The greater the accuracy the smaller the backlash needed. Backlash is most commonly created by cutting the teeth deeper into the gears than the ideal depth. Another way of introducing backlash is by increasing the center distances between the gears.

Backlash is undesirable in precision positioning applications such as machine tool tables. It can be minimized by tighter design features such as ball screws instead of lead screws, and by using preloaded bearings. A preloaded bearing uses a spring or other compressive force to maintain bearing surfaces in contact despite reversal of direction.

Anti-backlash gears

They are a relatively new addition to the gear industry. It offers a very high level of accuracy and control. It is available in various sizes and is specifically designed so that, when varying pressure is applied, the backlash can be easily set to match the needs of the application. The anti backlash gears are today available in a multitude of ratios that matches individual requirements. The anti Back lash gears are an effective medium for eliminating backlash in the gear trains.

Advantages of Anti Backlash Gears:

1- Anti-Backlash Gears results in doubling of machine speeds
2- Considerable reduction in vibration or internal stresses on the entire machine.
3- Reduced shock loads, resulting in quieter and smooth running.
4- Smoother power transmission.
5- Higher torque capabilities.

V- Gears materials

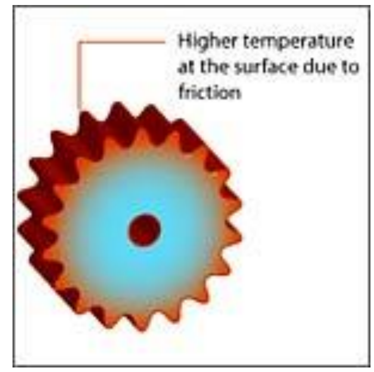
- Today there is a great variety of materials that are available to a gear designer. The designer can choose from a plethora of choices.
- Further, there are many ways to modify or process the materials. This improves the properties and side by side helps to minimize the cost of production. Actually the production process also plays a decisive role in the type of Gear Material. For example take the case of Machined gears, they are most precise. Now to manufacture them only that materials could be used that show good strength characteristics.

  The following table gives a good summary of the different materials used in the making of gears:

Material	Outstanding features	Applications	Precision Rating
Ferrous:			
Cast Iron	Low cost, good machining, high internal damping	Big size, moderate power rating, Commercial gears	Commercial quality
Cast Steel	Low cost, high strength	Power Gears, medium rating	Commercial quality
Plain Carbon Steel	Good machining, Heat treated	Power Gears, medium rating	Commercial to medium precision
Alloy Steels	Heat treated, high strength and durability	Strict power requirements	High precision
Stainless Steel	High corrosion resistance, nonmagnetic	Low power rating	Good Precision
Non Ferrous:			
Aluminum alloys	Light weight, noncorrosive, good machinability	Very light duty instrument gears	High precision
Brass alloys	Low cost, noncorrosive, good machinability	Low cost commercial equipment	Medium precision
Die cast alloys	Low cost, low strength	High production, low quality, commercial	Low grade commercial
Non Metallic:			
Nylon	No friction or lubricant, high water absorption	Long life, low nose, low loads	Commercial quality
Delrin	Wear resistant, long life	Low loads	Commercial quality

VI- Factors affecting selection of Gear Materials:

There are some very critical matters that need to be given a consideration before selecting a gear material. They are the following:



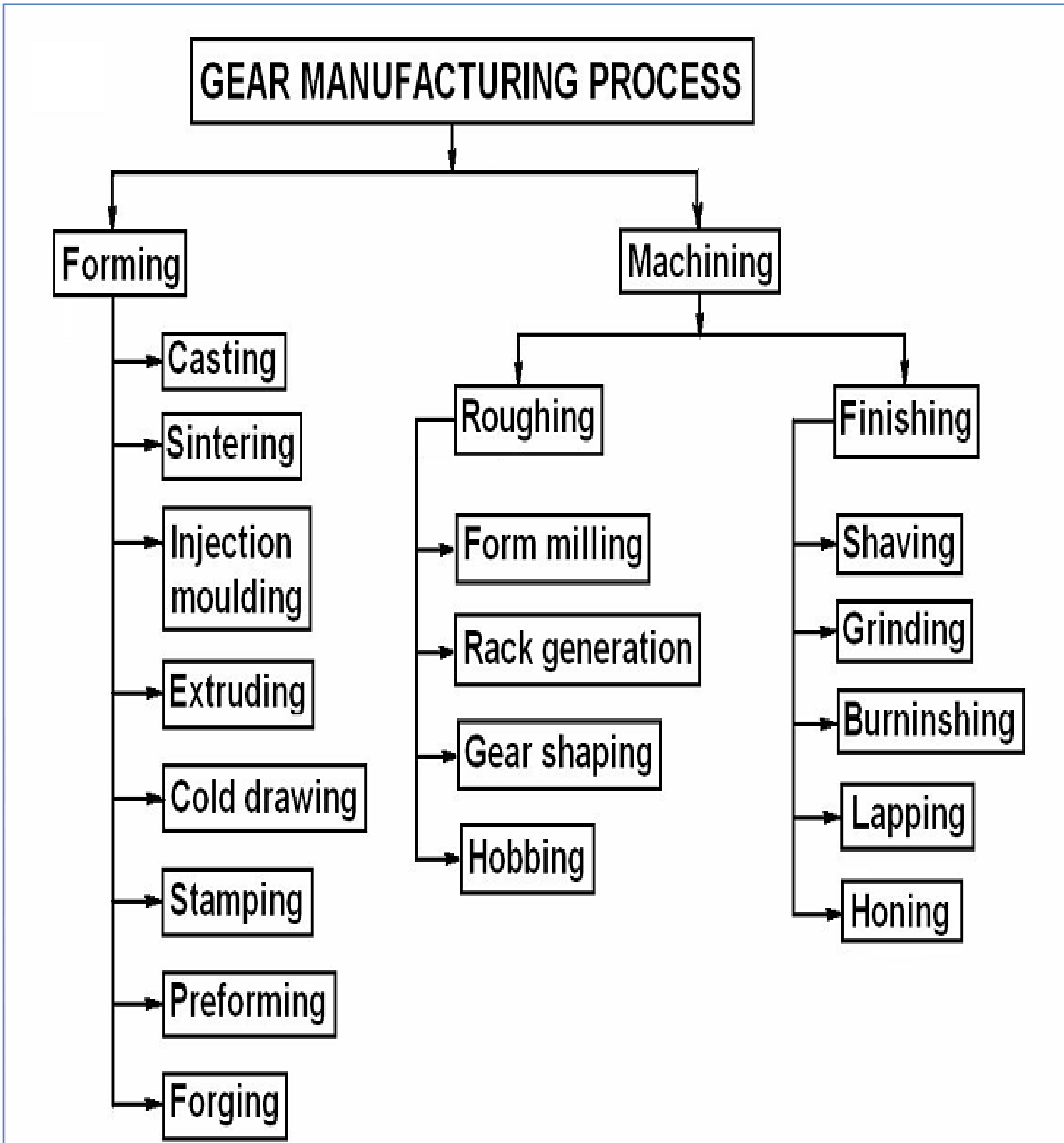
- Allowable bending and hertz stress
- Wear resistance
- Impact strength
- Water and corrosion resistance
- Manufacturing cost
- Size
- Weight
- Reliability
- Lubrication requirements
- No Moisture Absorption
- Dimensionally Stable
- Stress-Free structure
- Environmental and surface temperature-
  It has been found that if there is friction the surface temperature of the gear shows a tendency to raise.

Form of wear:

1) Pitting: It's the most serious defect due to the presence of dynamic loading and causes compressive stresses.
2) Abrasion: Due to the presence of foreign matter.
3) Scoring: Due to rough surface finish.
4) Scuffing: Due to the usage of improper lubricant.
5) Seizing: Due to insufficient lubricant accompanied by a locally generated heat which may cause local welding

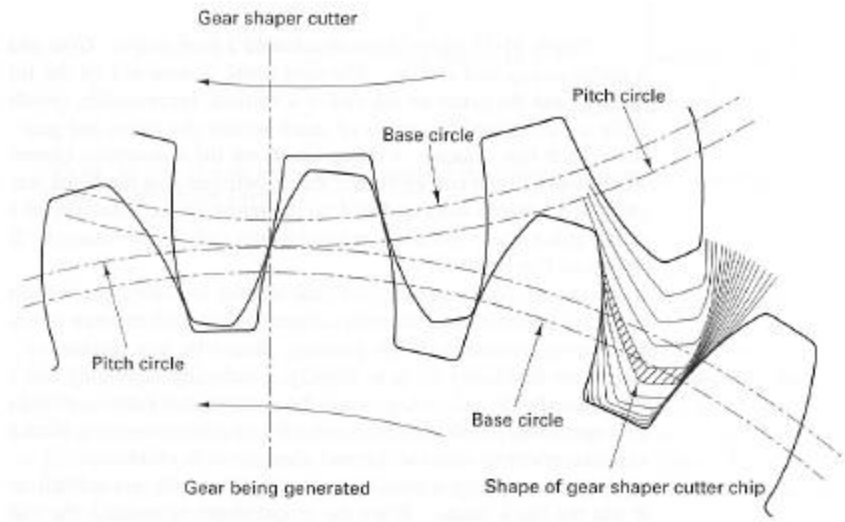
VII- Gear manufacturing methods

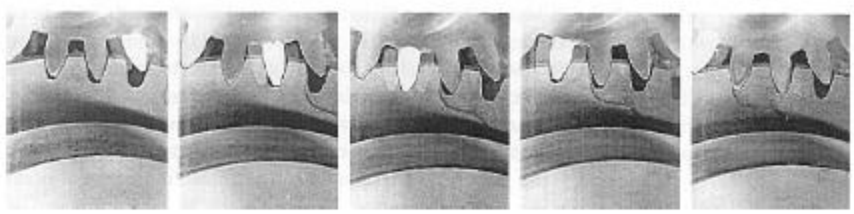
For the manufacture of gear wheels, comparatively complicated and highly precise machine tools are required. The wide variety of existing types of machines is the result of the effort made to find economic production methods for the geometrically diverse gear-tooth forms.



1. Generation

where the complicated tooth profile are provided by much simpler form cutting tool (edges) through rolling type, tool – work motions, e.g., hobbing, gear shaping etc.

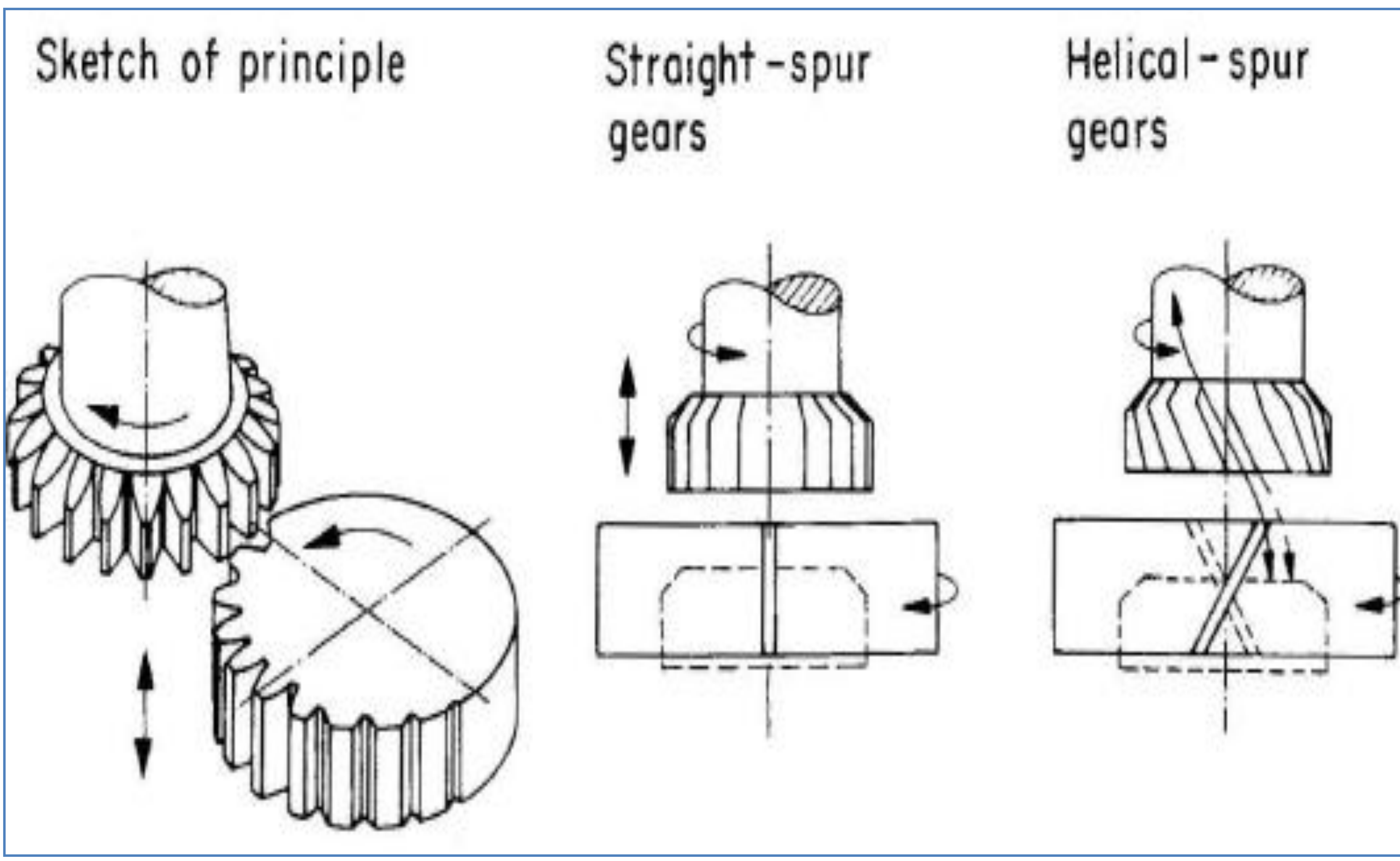




1.1. <u>Gear shaping</u>

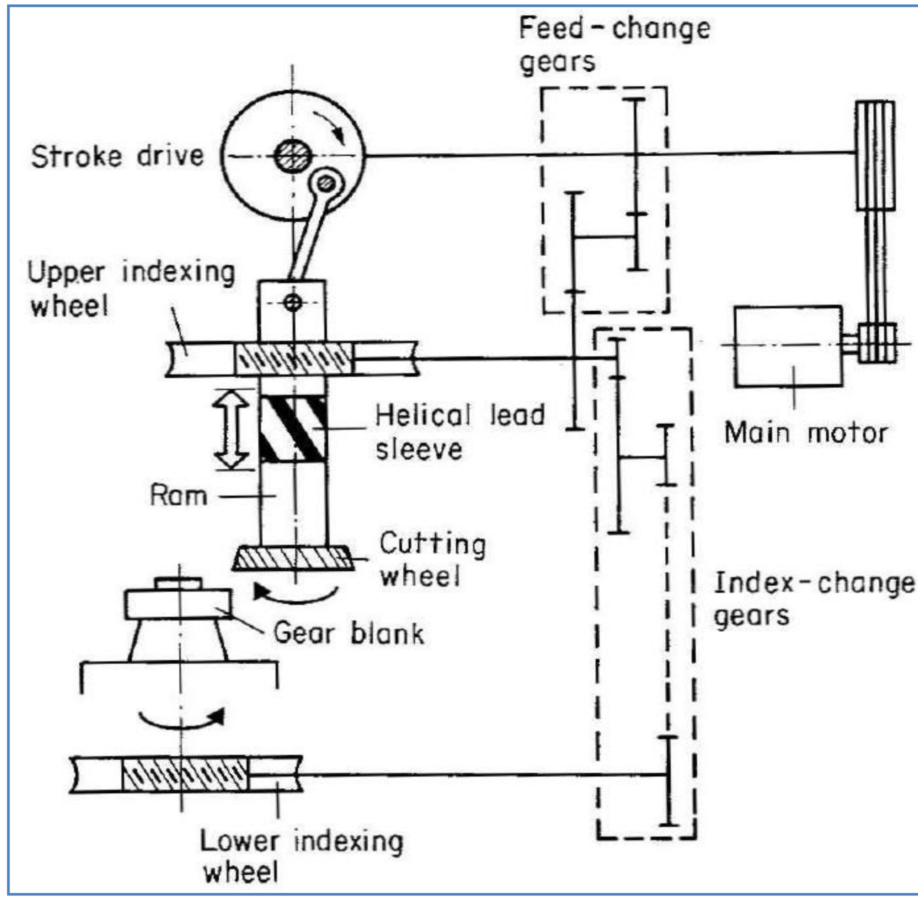
- Gear shaping is a method involving continuous generation. During gear cutting, the cutting wheel has a linear stroke movement (cutting movement) and simultaneously rotates with the gear blank.
- The cutting gear and the workpiece roll against each other like the gear and the mating gear of a spur gear. At the same time, the cutter for gear-shaping carries out the cutting motion through its oscillating slotting motion. A gearshaper is a machine tool for cutting the teeth of internal or external gears.
- The cutting tool is also gear shaped having the same pitch as the gear to be cut. However number of cutting teeth must be less than that of the gear to be cut for internal gears.
- For external gears the number of teeth on the cutter is limited only by the size of the shaping machine.

- In straight-toothed gears, the slotting motion corresponds with the part's axis direction.
- In helical teeth, the helical cutting gear performs the helical cutting motion according to the helix angle to be generated.
- The accuracy is good, but any errors in one tooth of the shaper cutter will be directly transferred to the gear.
- Advanced machines using this method obtain cutting speeds in excess of 100 m/min as a result of the application of high double-acting stroke rates.
- The ram spindle has a rotary motion during its stroke, guided by a helical lead sleeve. Such a helical lead sleeve, in combination with different cutting wheels, may be used for a specific range of helix angles.
- Gear shaping is mainly used for the production of internal gears and the manufacture of gears with a small free-axial space, e.g. double-helical and especially herringbone teeth, as well as for the cutting of gear clusters, etc.



The driving mechanism of gear shaper

The figureshows schematically the drive of a gear-shaping machine. To obtain the generating cutting action, four main movements are required.



- The rotary action of the cutting wheels
- Chip-producing motion continues through the working stroke
- The rotary action of the workpiece
- The return stroke

- The power transmission is direct from the main motor to the stroke mechanism. As the stroke movement is produced by a crank motion; the cutting speed is not constant throughout the whole Length of the stroke. During the return stroke a relieving motion is applied as otherwise, due to the continuous rotary action, interference between the gear blank and cutting tool would cause rubbing to take place.
- The rotary feed motion is picked up from the main drive through the feed change gears. The generating motion i.e. the co-ordination of the rotary motion of the tool and gear blank, is governed by the pick-off gear train and is transmitted to the ram spindle through the upper worm wheel, and to the work table through the lower worm wheel. At the beginning of the work cycle, the work table makes an additional radial movement, so that the desired depth of cut is obtained.

Gear Shaper Cutters

Gear	Properties	
Disc Type Shaper Cutter	Disc type cutters are effective for cutting **any type of gear**. Internal, external, spur, helical etc. They are also effective for cutting sprockets, splines or other types of involute forms. Popular cutters have bore diameters between 10mm-120mm or ½" to 4".	

Shank Type Cutters	They are essentially designed to cut ***internal gears***, both spur and helical. Can also be designed for externals. These are full form generated cutters whatsoever be the pitch circle diameter (PCD). A bit of problem in the shank type cutters is the strength factor.	
Disk Type Helical Shaper Cutter	This cutter is applied to cut ***helical gears***. The helix angle of the gear determines the number of teeth that the cutter would have.	
Deep Counter- bore Type Shaper Cutter	This type of cutter is commonly applied to cut shoulder gears.	
Convex Cutter	Straight Bevel Gears are easily cut with Convex gear cutter. Convex gear cutters produce gear teeth with an accurate tooth contact, So the gears made this way operate in a smoothfashion.	

Pinion Type Cutter	Pinion type cutters are typically shaped like Spur Gears. The Pinion type cutters are adept in cutting teeth of the internal gears.	
Spiral Bevel Cutter	As is seen from the image Spiral Bevel cutters are shaped like crowns and they are used to generate Spiral Bevel gears.	

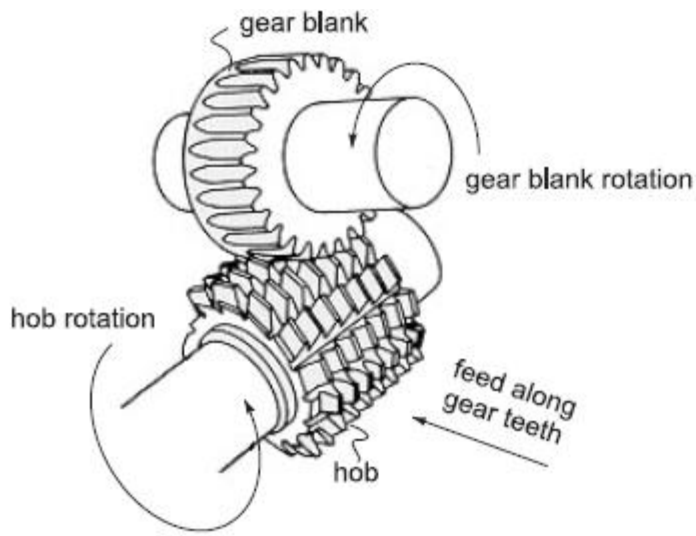
1.2. Hobbing:

Introduction:

- Hobbing is the process of generating gear teeth, splines, and sprockets by means of a rotating cutter called hob on a hobbing machine. It is continues indexing process in which both the cutting tool & work-piece rotate in a constant relationship while the hob is being fed into work.
- Each hob tooth cuts its own profile depending on the shape of cutter.

Compared to other gear forming

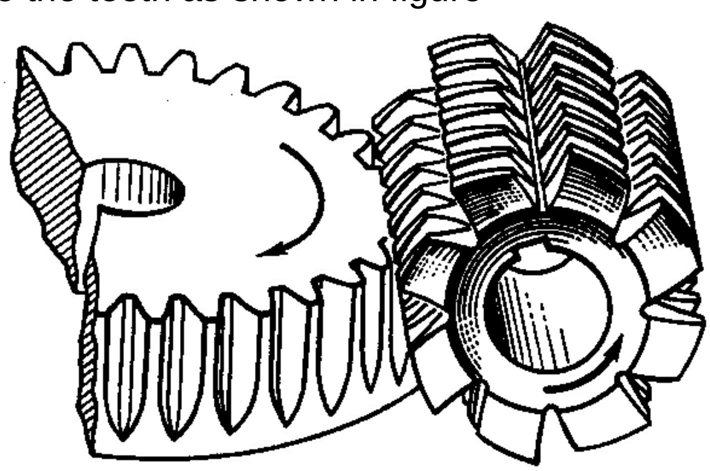
processes it is relatively inexpensive but still quite accurate, thus it is used for a broad range of parts and quantities



Setup of gear hobbing opeartion.

Process

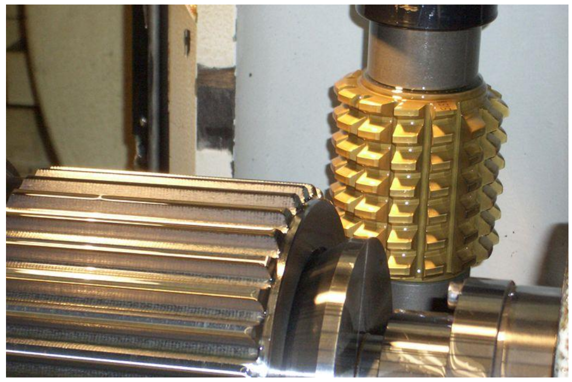
Hobbing uses a hobbing machine with two non-parallel spindles, one mounted with a blank work-piece and the other with the hob. The angle between the hob's spindle and the work-piece's spindle varies depending on the type of product being produced. For example, if a spur gear is being produced, then the hob rotates about an axis normal to that of the gear blank, cutting into the rotating blank to generate the teeth as shown in figure



The two shafts are rotated at a proportional ratio, which determines the number of teeth on the blank; for example, if the gear ratio is 40:1 the hob rotates 40 times to each turn of the blank, which produces 40 teeth in the blank.

Most hobbing machines are vertical hobbers, which mean the blank is mounted vertically.

Horizontal hobbing machines are usually used for cutting longer work-pieces; i.e. cutting splines on the end of a shaft.



Types of Hobbing

1) Arial hobbing:-

This type of feeding method is mainly used for cutting *spur or helical gears.* In thistype, firstly the gear blank is brought towards the hob to get the desired tooth depth.

The table side is them clamped after that, the hob moves along the face of the blankto complete the job. Axial hobbing which is used to cut spur & helical gears can be obtained by climb noting or conventional hobbing.

2) Radial hobbing:-

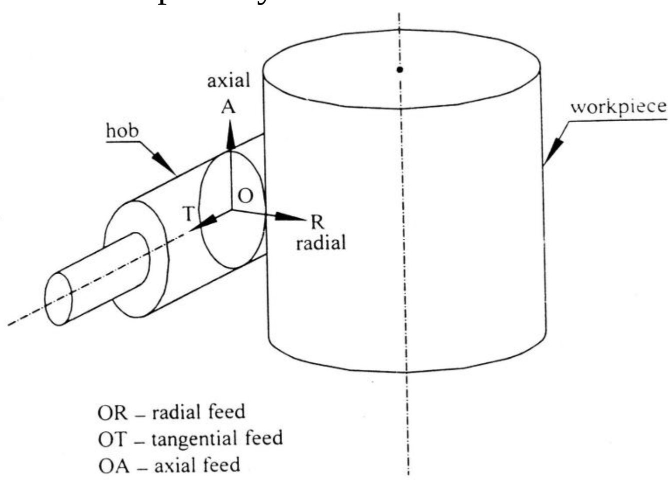
This method of hobbing is mainly used for cutting worm wheels. In this method the hob & gear blank are set with their ones normal to Each other. The gear blankcontinues to rotate at a set speed about its vertical axes and the rotating hob is givena feed in a radial direction. As soon as the required depth of tooth is cut, feed motionis stopped.

3) Tangential hobbing:-

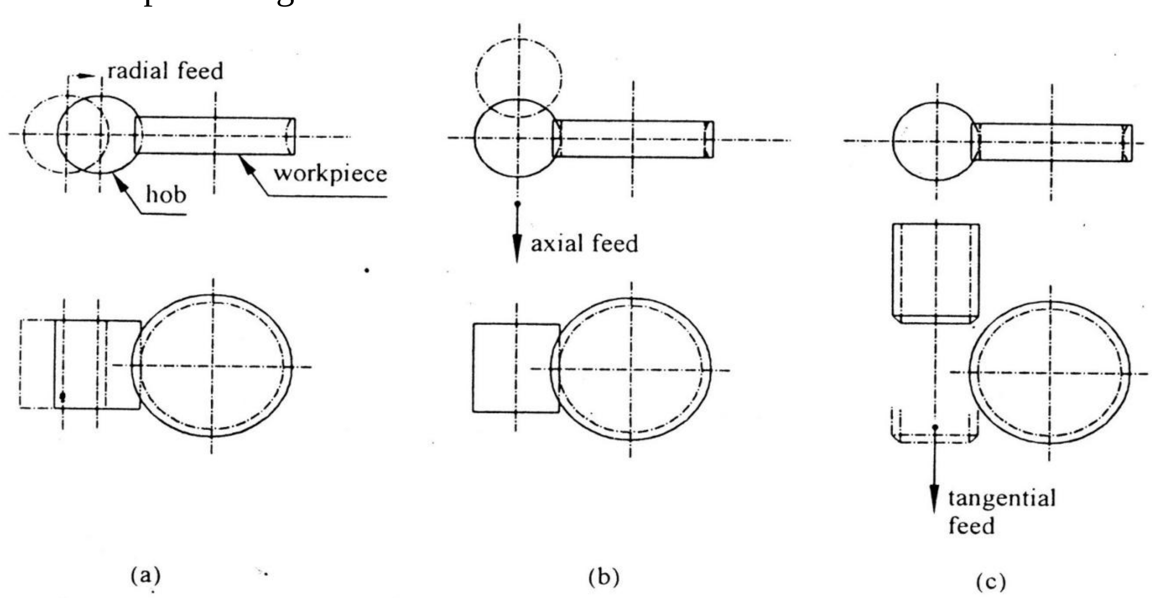
This is another common method used for cutting worm wheel. In this method, the worm wheel blank is rotated in a vertical plane about horizontal axes. The hob is also held its axis or the blank. Before starting the cut, the hob is set at full depth ofdie tooth and then it is rotated. The rotating hob is then fed forward axially. Thefront portion of the hob is tapered up to a certain length & gives the fed in tangentialto the blank face & hence the name Tangential feeding.

Feed motions of hob cutters

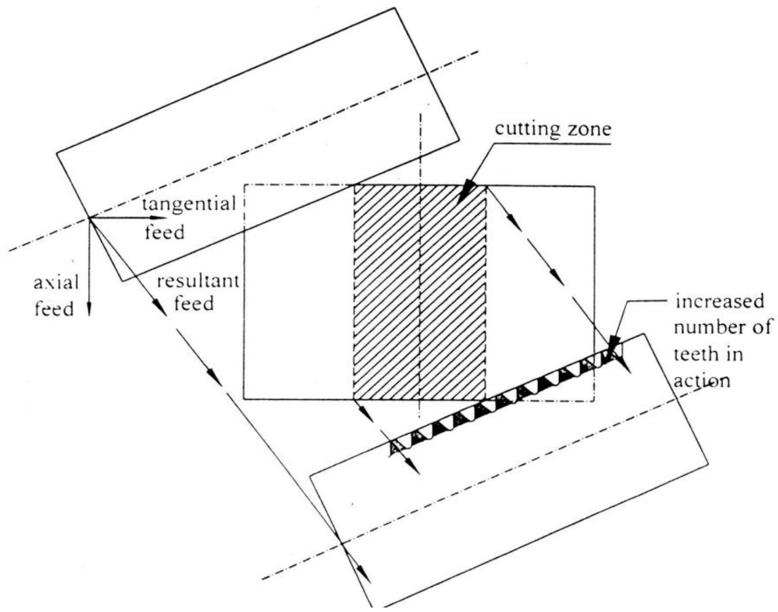
- Figures of feed motion of hob show the cutting of teeth on the work piece with the hob. There are three principal feed motions with respect to the work piece [Figs. 5 (a), (b) and (c)]. Feed motion in the direction OR is the radial-feed motion. It is called radial because it is in the radial direction of the work piece. Feed motions in the directions of OA and OT are called axial-feed motion and tangential-feed motion, respectively. There can be feed motions which are combination of any two of these primary feed motions.



- Axial feed is the most commonly used feed, unless there is restriction for axial motion. The hob is fed to the full depth form and then fed in axial direction to generate the full width of the gear. Radial feed is used where there is restriction to axial motion; In this case the hob is fed in radial direction.
- In tangential feed, the hob moves at a direction tangential to the gear being cut. This method of cutting is used for producing worm wheels.



- When any two of these feeds are used together, we get a resultant feed which is dependent on the ratio of the two feeds. The most commonly used combined feed is called diagonal hobbing in which tangential and axial feed are used simultaneously. This is shown in fig. normally in radial and axial feed.

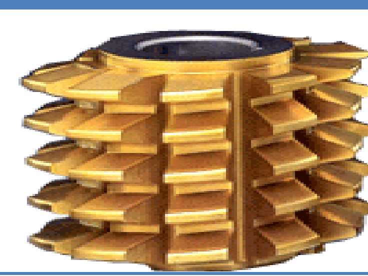


- Accuracy of the gear produced by diagonal hobbing depends on the accuracy of the hob over the number of teeth, and it's pressed over number of teeth. As in radial and axial feed only a limited number of teeth do the actual cutting, the wear of the hob will be concentrated only on these few teeth.

Applications of hobbing

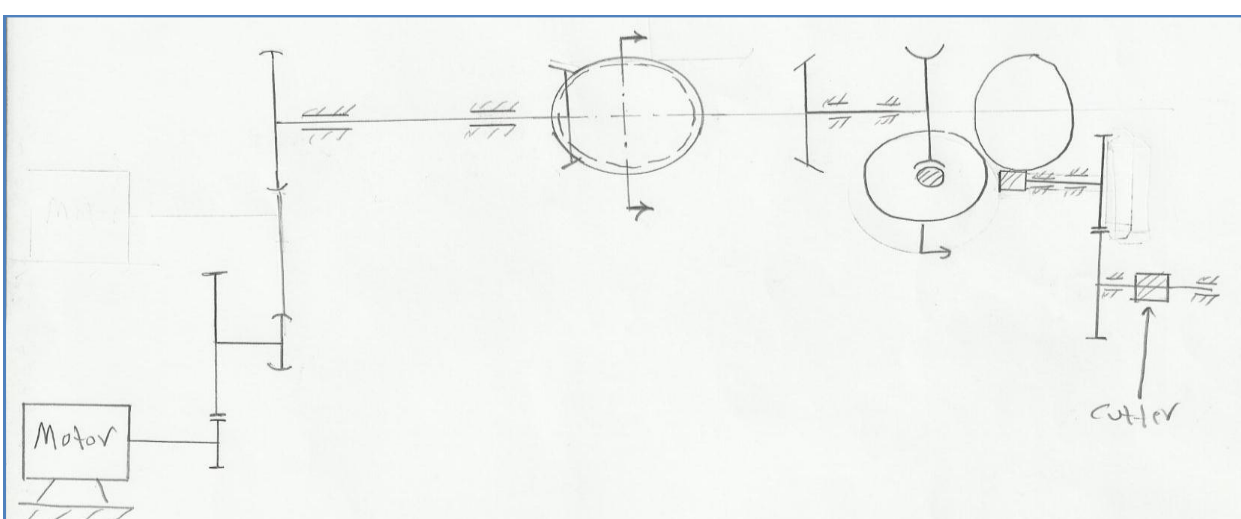
Hobbing is widely used to produce spur, helical gears, worms and worm wheels. It can also be used for producing internal gears for which the machine should have facility for fitting a special head. Hobbing cannot be used where gear is to be produced close to the shoulder having diameter bigger than the root diameter of the gear. Double-helical gear can be hobbed if there is sufficient gap between the helices for the hob over travel.

Types of gear hobs

Gear	Properties	
Involute gear hob	They can generate gears with maximum precision. They are used when there would be no tooth finishing operation afterwards and there is need for better precision before tooth shaving operations.	

Involute Spline	They have a unique stud tooth depth to cut all types of standard or nonstandard involute Splines.	
Sprocket Hobs	They are used for cutting roller chain sprockets for a range spanning from 1/4th inch-3 inch pitch. Can be produced in single or multi start.	
Worm Wheel Hobs	They are designed for plunge cutting. The Worm wheel hobs are unique in a way; they match the worm shaft with sharpening allowance. They can be of shank or shell type.	
Serration Hob	They are designed for cutting the serrations as per job. They give high accuracy.	

Indexing:

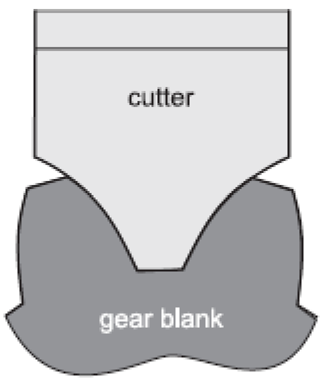


Comparison between shaping and hobbing

Features	Hobbing	Shaping
Accuracy	Better with respect to tooth spacing and runout. Equal so far lead accuracy is required.	Better w.r.t. tooth form.
Surface finish	Hobbing produces a series of radial flats based on feed rate of hob across the work.	Shaping produces a series of straight lines parallel to the axis of the gear. As the stroking rate can be varied independently of rotary feed, the numbers of enveloping cuts are essentially more than the same for a hobbed gear. Surface finish may be better.
Internal gear and gear shoulder	-Cannot be used for internal gears. -Hob diameter determines the limitation of cutting gear with shoulder.	-Can be used for internal gears -Can cut up to shoulder with very little clearance.
Limitation	For helical gears, only differential gearing is used which again can be eliminated in CNC hobbing -More time for wide gears	Each helix and hand requires a separate helical guide. No CNC system to replace helical guide is still developed.
Production rate	Hobbing is faster than shaping even for gears with narrow face widths.	With high speed stroking, **narrow width** job can be finished in lesser time than by hobbing.

2. Form Cutting

In gear form cutting, the cutting edge of the cutting tool has a shape identical with the shape of the space between the gear teeth; e.g., milling, broaching, etc.

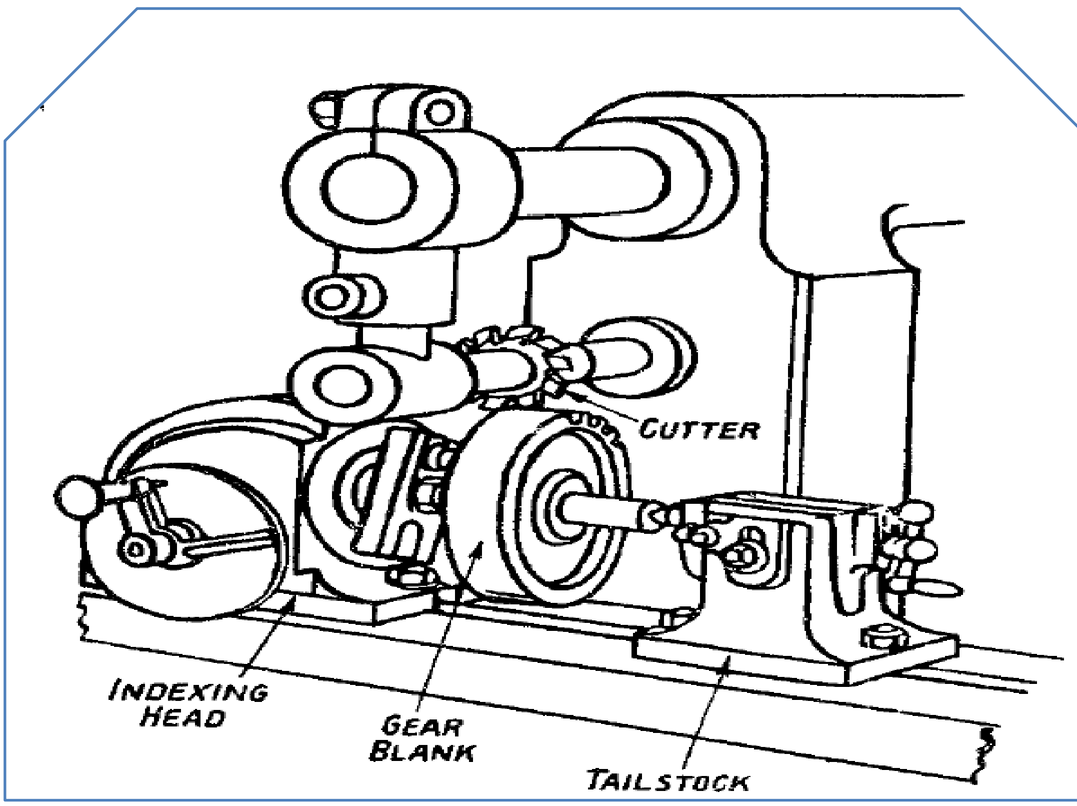


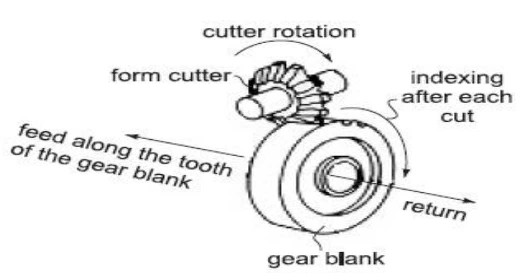
The principle of gear forming.

2.1. Milling

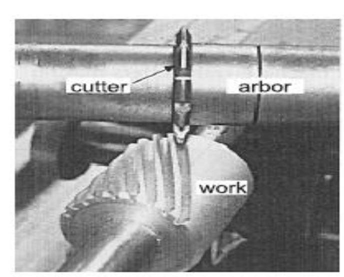
- In formmilling, the cutter called a formcuttertravels axially along the length of the gear tooth at the appropriate depth to produce the gear tooth.
- After each tooth is cut, the cutter is withdrawn, the gear blank is rotated (indexed), and the cutter proceeds to cut another tooth. The process continues until all teeth are cut.

- Each cutter is designed to cut a range of tooth numbers.
- The precision of the form-cut tooth profile depends on the accuracy of the cutter and the machine and its stiffness.





Setup of form milling.



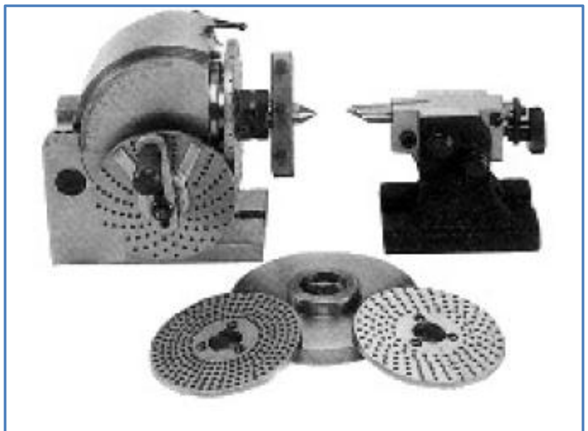
Form milling of a helical gear.

Indexing:

- In form milling, indexing of the gear blank is required to cut all the teeth.
- Indexing is the process ofevenly dividing the circumference of a gear blank into equally spaced divisions.

- The index head of theindexing fixture is used for this purpose.

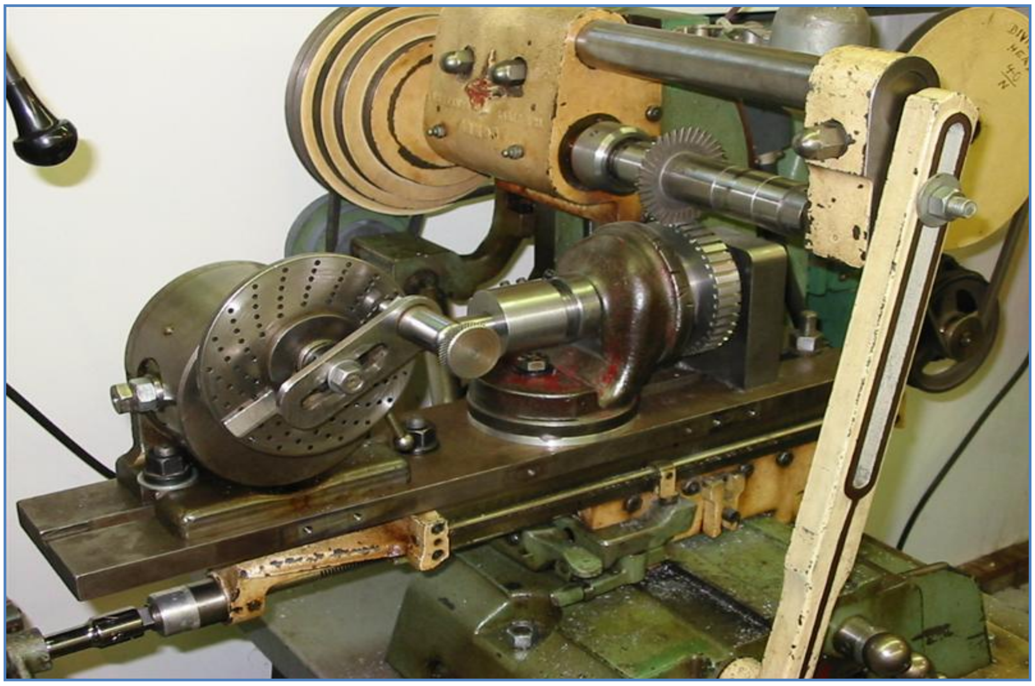
- The index fixture consists of an index head (also dividing head, gear cutting attachment) and tail stock. The index head and tail stock attach to the worktable ofthe milling machine. An index plate containing graduations is used to control the rotation of the indexhead spindle. Gear blanks are held between centers by the index head spindle and footstock. Workpieces may also be held in a chuck mounted to the index head spindle or may be fitted directly into the taperspindle recess of some indexing fixtures.



Dividing head (*Left*), and footstock (*Right*) used to index the gear blank in form milling.

Types of indexing on milling:

1- Plain indexing.
2- Compound indexing.
3- Differential indexing.



Worm drive speed ratio= 40:1 (standard)
Index plate standards:
BS:

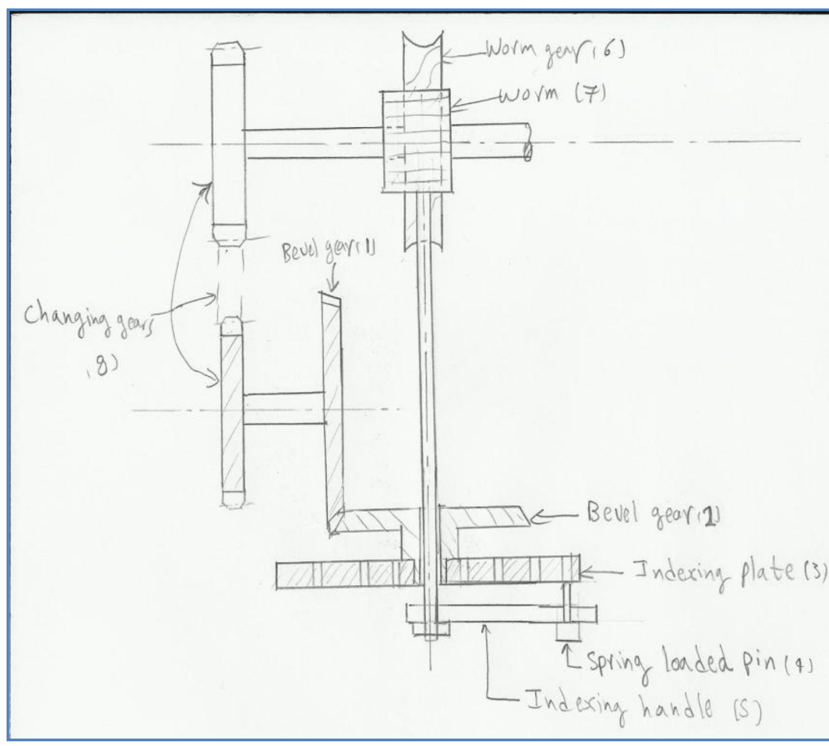
Plate code	Available no. of holes in each circle					
1	15	16	17	18	19	20
2	21	23	27	29	31	33
3	37	39	41	43	47	49

AS:

Plate code	Available no. of holes in each circle										
1	24	25	28	30	34	37	38	39	41	42	43
2	46	47	49	51	53	54	57	58	59	62	60

Changing gears standards:
24, 24, 28, 32, 40, 44, 48, 56, 64, 72, 86, 100

1- Simple indexing:



Simply rotate the indexing handle (5), so the worm rotates making a lead causing worm gear to rotate by 1/40 rotation (9 degrees)
To make a gear with this type:
40: no. of teeth of gear= moved holes: total no. holes in a circle
Example: According to BS
For z= 60
40/60: 2/3= 10/15= 12/18= 14/21= 18/27= 22/33= 26/39
So circle of 15, 18, 21, 27,33 or 39 could be used
With moved circles: 10, 12, 14, 18, 22 or 26 respectively

2- Compound indexing:

For gears of no. of teeth which couldn’t be performed by simple indexing
The spring loaded pin is disengaged from the hole in the index plate, so the index plate can be moved relative to the indexing handle
Relative motion may be in the same direction of rotation of indexing handle, so real rotated angle < rotated angle of index

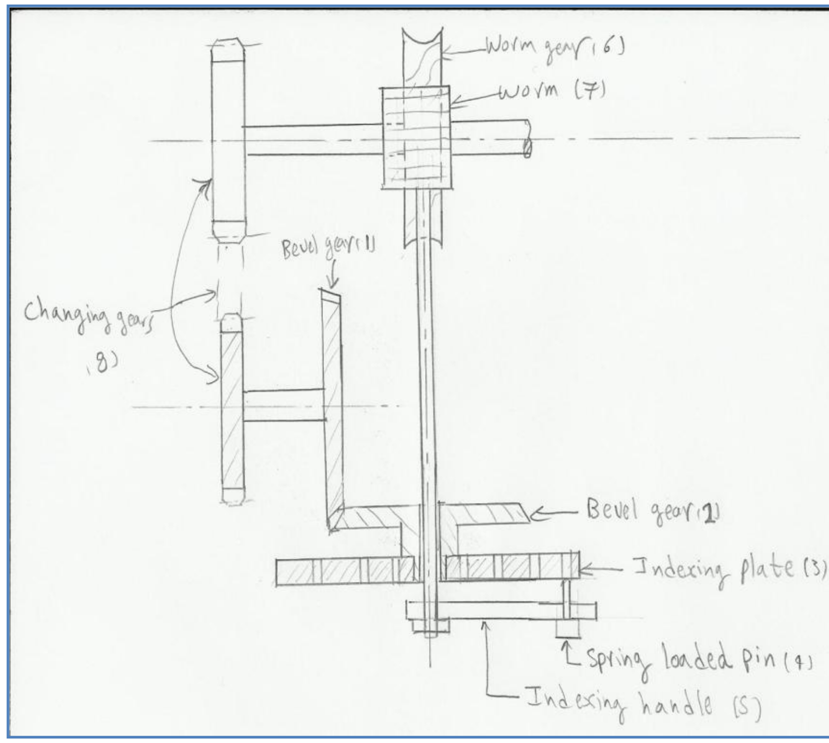
$Z_{\text{compound indexing}}$ is more than $Z_{\text{simple indexing}}$ by reduction ratio at changing gears and vice versa

Example

Z= 93 $\Longrightarrow \frac{40}{93} = 2\frac{13}{93} = 2\ rotations + 13\ hole\ from\ circle\ of\ 93\ holes \Longrightarrow doesn't\ f$

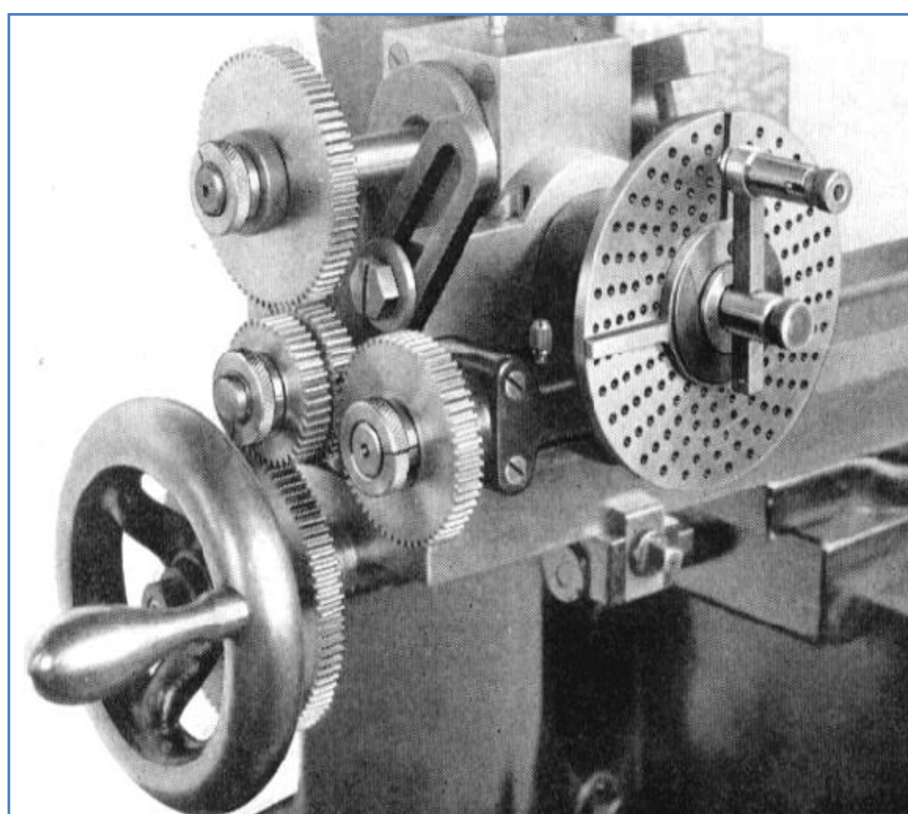
This gear could be manufactured as following

1. 2 rotations from index handle
2. The no. of teeth could be got by simple gearing numerically as $Z_{\text{approx.}}$= 90
   $\frac{40}{90} = \frac{4}{9} = \frac{8}{18} \Longrightarrow 8\ holes\ f$
3. Reduction ratio in gears = $\frac{|Z_{approx} - Z_{real}| \times 40}{Z_{approx}} = \frac{|90-93| \times 40}{90} = 3$



Finally

1. Rotate the index handle 2 rotations
2. Install a gear set of reduction ratio 3
3. Rotate 8 holes from a circle of 18 holes

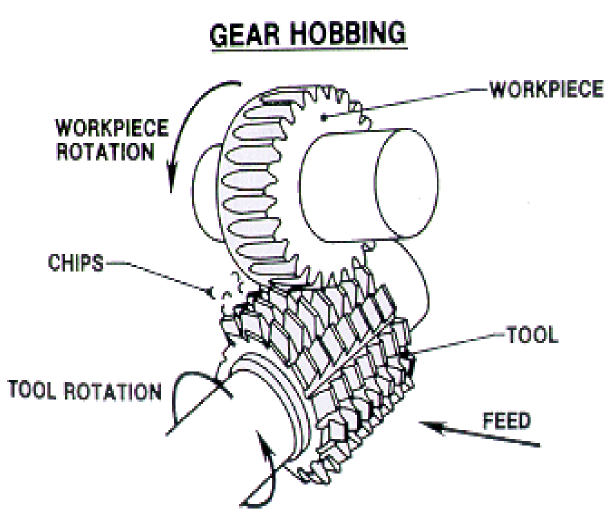


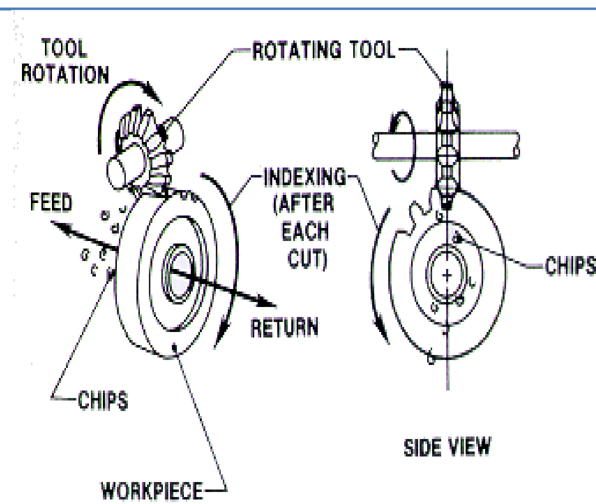
Gear milling cutters:

Gear Cutter	Properties	
Side and Face Milling Cutters	They can be supplied either in staggered or in straight tooth form. They can be used for operations involving light or heavy deep slot. The Side Milling Cutters are good choice for steel.	
Convex Cutters	Convex cutters operate on a very high speed for cutting gear teeth.	
Concave Cutters	They are also high speed operators to be used on all types of material.	
Single and Double Angle Cutter	Single cutters are used for beveling, they can be produced in single right and left angle. Double angle cutters are used for serrations, grooves and other angular surfaces.	
Involute Gear Cutter	Involute Gear Cutters can cut a vast number of teeth in gears. Like 0.5 module to 50 even module. Also there is a wide choice of diametric pitch.	

Comparison between Gear hobbing and milling

Gear Hobbing	Gear Milling
Gear hobbing is a multipoint machining process in which gear teeth are progressively generated by a series of cuts with a helical cutting tool (hob). Both the hob and the work-piece revolve constantly as the hob is fed across the face width of the gear blank.	Gear milling is a multipoint machining process in which individual tooth spacing is created by a rotating multi-edge cutter having a cross-section similar to that of the generated teeth (involute). After cutting each space, the gear is returned to its original position, and the gear blank is indexed for the next cut.
Process Characteristics:	**Process Characteristics:**
- Is a gear generating process that uses a helical hob cutter - Cutters and blanks rotate in a timed relationship - Maintains a proportional feed rate between the gear blank and the hob - Cuts several teeth on a progressive basis - Is used for high production runs	- Uses a rotating form cutter - Gear blanks are indexed after each cut - Gear teeth are produced individually - Requires deburring - Is a low production process -Is normally used only when generating processes (i.e., hobbing, shaping) are unavailable



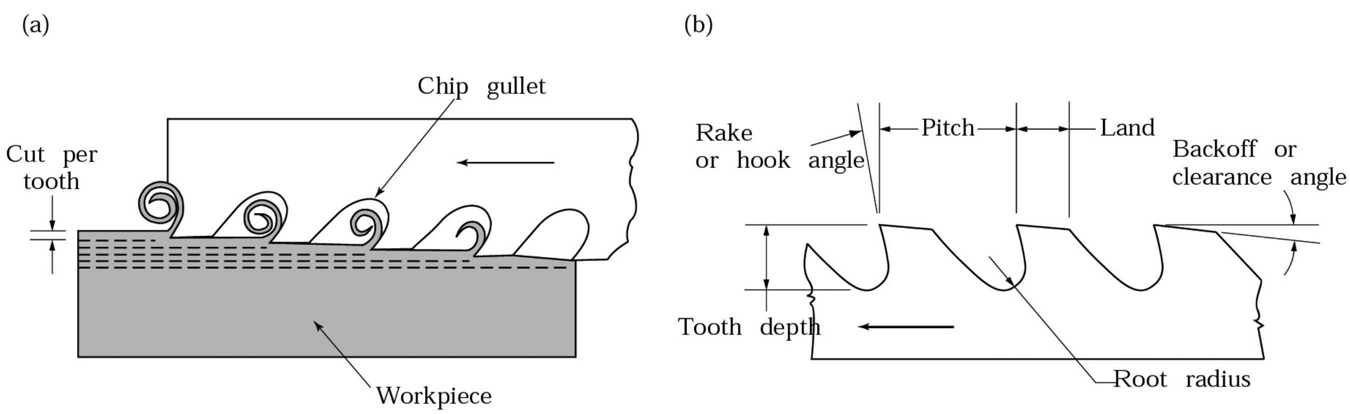


2.2. Broaching

Broaching is a metal cutting technique with a multi-edged tool in which the tool performs the cutting motion

It is a high-production machining operation that involves the one-way a broach, a cutting tool with a series of progressively stepped teeth. The teeth move parallel to the surface being machined and each one removes a precise amount of material. The spaces between the teeth hold the chips until the teeth pass from the workpiece. One pass of the broach results in the completion of the operation. The broach can be pulled or pushed across the work.

This method functions without any feed motion due to the offset of the cutting teeth on the broaching tool.



The initial teeth to contact the workpiece are often designed to provide a roughing cut, while the final teeth provide finishing to the dimension desired. The process is rapid and produces fine surface finish with high dimensional accuracy. However, because broaches are expensive-and a separate broach is required for each size of gear-this method is suitable mainly for high-quantity production

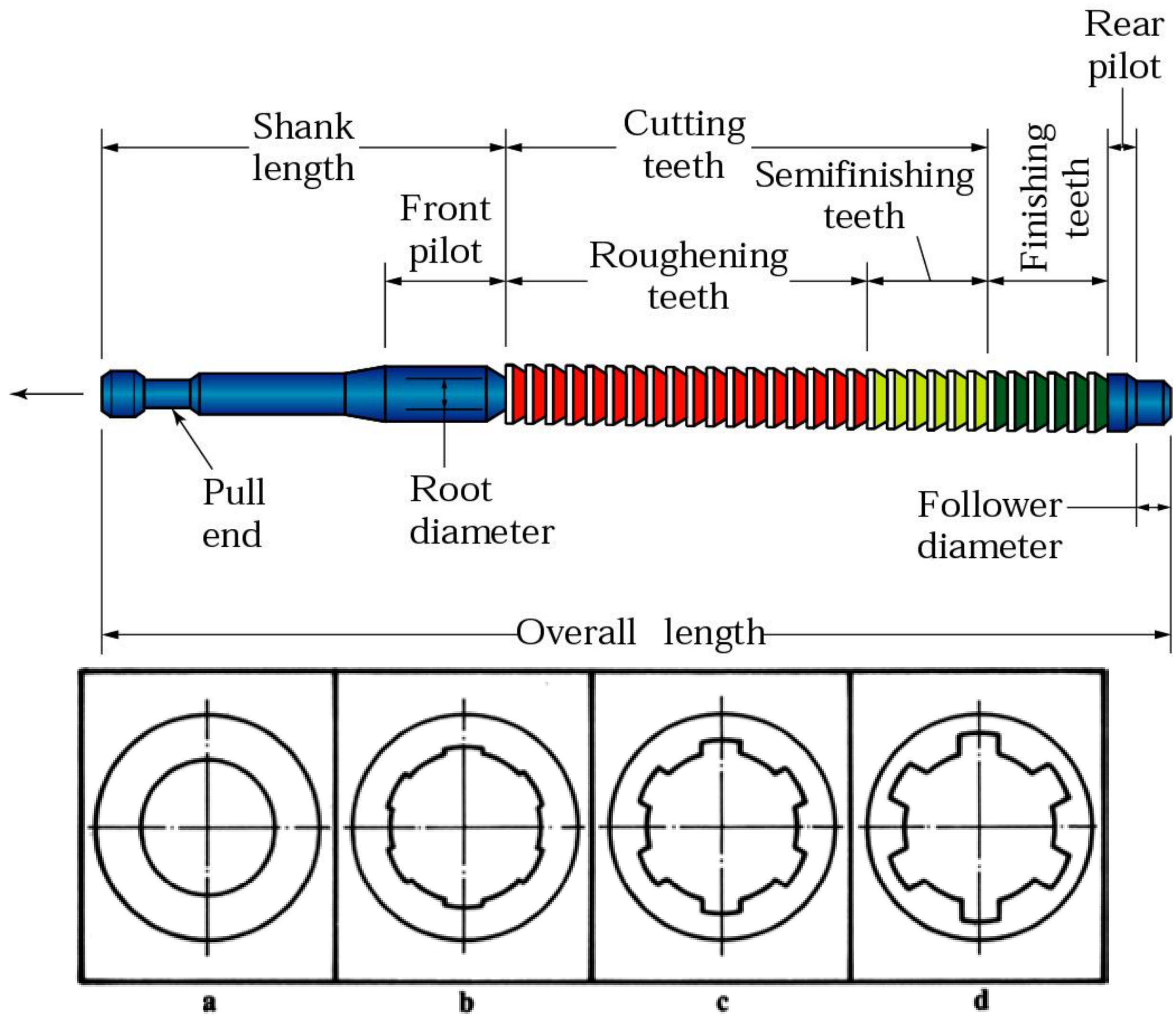
Teeth of small internal and external spur gears; straight or single helical, of relatively softer materials are produced in large quantity by this process.

Applying a twisting action either to the cutter or the work may enable broaching of helical gears.

Internal broaching

During internal broaching, the broaching tool is brought into the premachined opening of the workpiece. Working motion then begins, whereby the broach, equipped with many cutting blades, is pulled or pushed through.

Helical gears can be cut with helical broaches if the workpiece is rotated as the broach advances.



Generation of an internal spline during internal broaching
a - before; b and c – during; d – at the end of the broaching procedure

External broaching

External broaching is the method used for the generation of external profiles.